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PB-257 698

A Measurement of RF Field Intensities in the Immediate Vicinity of an FM Broadcast Station Antenna

Office of Radiation Programs, Washington, D C

Jan 76

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United States Environmental Protection Agency

Office of Radiation Programs Washington, D.C. 20460

ORP/EAD-78-2 January 1978

Radiation

PB 257 698

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Technical Note

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U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. ORP/EAD 76-2	2.	3. Recipient's Accession No.
4. Title and Subtitle A Measurement of RF Field Intensities in the Immediate Vicinity of an FM Broadcast Station Antenna			5. Report Date January 1976 6.
7. Author(s) R. A. Tell			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Environmental Protection Agency, Office of Radiation Programs AW-461 Washington, D.C. 20460			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Same as item 9			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

An FM broadcast tower was surveyed to determine the radiofrequency exposure levels to which personnel working on such towers would be exposed during such tasks as painting, beacon replacement, repairs to de-icing equipment, antenna adjustment, and tower rigging and replacement. High intensity radiofrequency fields in excess of 180 mW/cm^2 were found on the tower. To prevent a worker's exposure from exceeding OSHA standards, he would be allowed to work in this field only 20 seconds in each 6 minute period. Since this is impractical, it was suggested that tower work be performed only when the transmitter is turned off.

17. Key Words and Document Analysis. 17a. Descriptors

Environment, FM broadcast antenna, Nonionizing radiation, Radiofrequency

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	UNCLASSIFIED	13
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.50-3.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

Technical Note
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A MEASUREMENT OF RF FIELD INTENSITIES IN THE IMMEDIATE VICINITY OF AN FM BROADCAST STATION ANTENNA

R. A. Tell

January 8, 1976

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PREFACE

The Office of Radiation Programs of the Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and nonionizing radiation, and to promote the controls necessary to protect the public health and safety. This report gives the results of a study of electric-field energy density on the antenna tower of a frequency-modulated (FM) broadcast station. Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors.

Floyd L. Galpin

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A MEASUREMENT OF RF FIELD INTENSITIES IN THE IMMEDIATE VICINITY OF AN FM BROADCAST STATION ANTENNA

INTRODUCTION

In a recent study of broadcast radiation levels, measured values of the radiation intensity on an FM broadcast tower were obtained. The measured values could lead to exposures in excess of established standards and suggest the need for corrective action to protect operating and maintenance personnel who must climb these towers.

As of January 1975, there were 4,434 AM radio stations, 3,373 FM radio stations, and 953 TV stations operating in the United States [1]. A number of activities require work on broadcast towers including painting, beacon replacement, repairs to de-icing equipment, antenna adjustment, and tower rigging and replacement. It is common practice for this tower work to be done while the broadcast station is operating at full power. No attempt has been made to quantitate the duration of exposure associated with the tasks enumerated above, but exposure times are significant for some of them, i.e., greater than one hour. The size of the exposed group is also unknown. In some cases maintenance is performed by station personnel, on others the work is performed by a contractor whose organization may service many towers.

Though experimental and theoretical values for radiofrequency exposure levels in the general vicinity and at the tower base of FM and TV broadcast antennas have been published [2-4], measured values of radiofrequency levels in and on the towers supporting broadcast antennas are not available. But undocumented reports by tower maintenance personnel of the sensation of warmth when climbing energized broadcast towers indicate the possibility of intense radiofrequency fields near the antennas radiating structures. The published values for heating sensation [5] exceed the current Occupational Safety and Health Administration (OSHA) radiofrequency exposure standard of 10 mW/cm^2 [6]. This is to say that current standards applicable to this situation are established at levels below the threshold of heat sensation. The threshold data for heating are for higher frequencies than the FM band, i.e., for 3,000 and 10,000 MHz, but are pertinent at the lower frequencies since there is recent evidence that man's resonant absorbtion frequency may occur in the vicinity of 80 MHz [7,8].

SOURCE DESCRIPTION

The measurements reported here were obtained as part of a larger study of ground level environmental radiofrequency radiation levels on Mt. Wilson conducted in cooperation with the Los Angeles County Department of Health Services. The results of the ground level measurements are reported elsewhere [9]. Located in close proximity on Mt. Wilson are 27 broadcast stations (12 FM radio stations and 15 television stations) serving the greater Los Angeles area. The measurements reported here were made November 20, 1975, on a tower supporting a single FM station. The station transmits 24 hours a day with 105 kilowatts (kW) of effective radiated power (ERP) in

both the horizontal and vertical planes using circular polarization. FM broadcast stations are authorized a maximum ERP of 100 kW in each plane by the FCC. Certain stations, such as this one, which were licensed before September 10, 1972, may continue operation at their originally authorized power. A total transmitter power of 40 kW is fed to a Jampro model JSCP-6, 6 bay, circularly polarized antenna which is mounted to the side of a pole which is in turn mounted to the side of the tower. The tower is 120 feet high and the antenna center of radiation is about 80 feet above ground. The tower is of the selfstanding type with an interior ladder for convenience in climbing. The Jampro antenna provides a gain of 7.17 dB relative to an isotropic antenna. Figure 1 is a photograph of several FM and TV broadcast towers on Mt. Wilson and shows the measured exposure data for the tower under investigation on the left. Three other FM transmitting antennas are shown with each bay circled for clarity.

MEASUREMENTS

Measurements were made with an electric field energy density meter, model EDM-3, designed and developed by the National Bureau of Standards in Boulder, Colorado. This instrument consists of a small, orthogonally arranged group of three dipolar elements, with a detecting diode at each element's center. The detected signal, consisting of a dc voltage, is fed to the electronic readout circuitry thru very high resistance, semiconducting lines. The active probe is at the end of a 1.2 meter long wand which is used as a handle and the overall probe unit has the desirable properties of not perturbing the field in which it is immersed and is isotropic in response, i.e., it measures energy density independent of its orientation in the field. The meter is calibrated to give electric field energy density, U_E, in units of microjoules per cubic meter ($\mu J/m^3$). For conversion of the meter readings to equivalent, far field power density, S, the following relation is used [10]:

$$S\ (mW/cm^2) = 60.0\ U_E\ (\mu J/m^3) \qquad (1)$$

Alternatively, the near-field electric field strength squared E^2 in units of volts squared per meter squared (V^2/m^2) is expressed as:

$$E^2\ (V/m)^2 = \frac{2\times10^{-6}\ U_E\ (\mu J/m^3)}{\varepsilon_o\ (F/m)} \qquad (2)$$

ε_o is the permittivity of free space and is equal to 8.854×10^{-12} farads/meter (F/m). The units of V^2/m^2 are used as another method of quantifying the exposure in the near field as provided for in the American National Standards Institute (ANSI) standard [11] and this unit is related directly to the measured electric field energy density without assumptions about the relationship between the E and H field components. The values of V^2/m^2 provide a

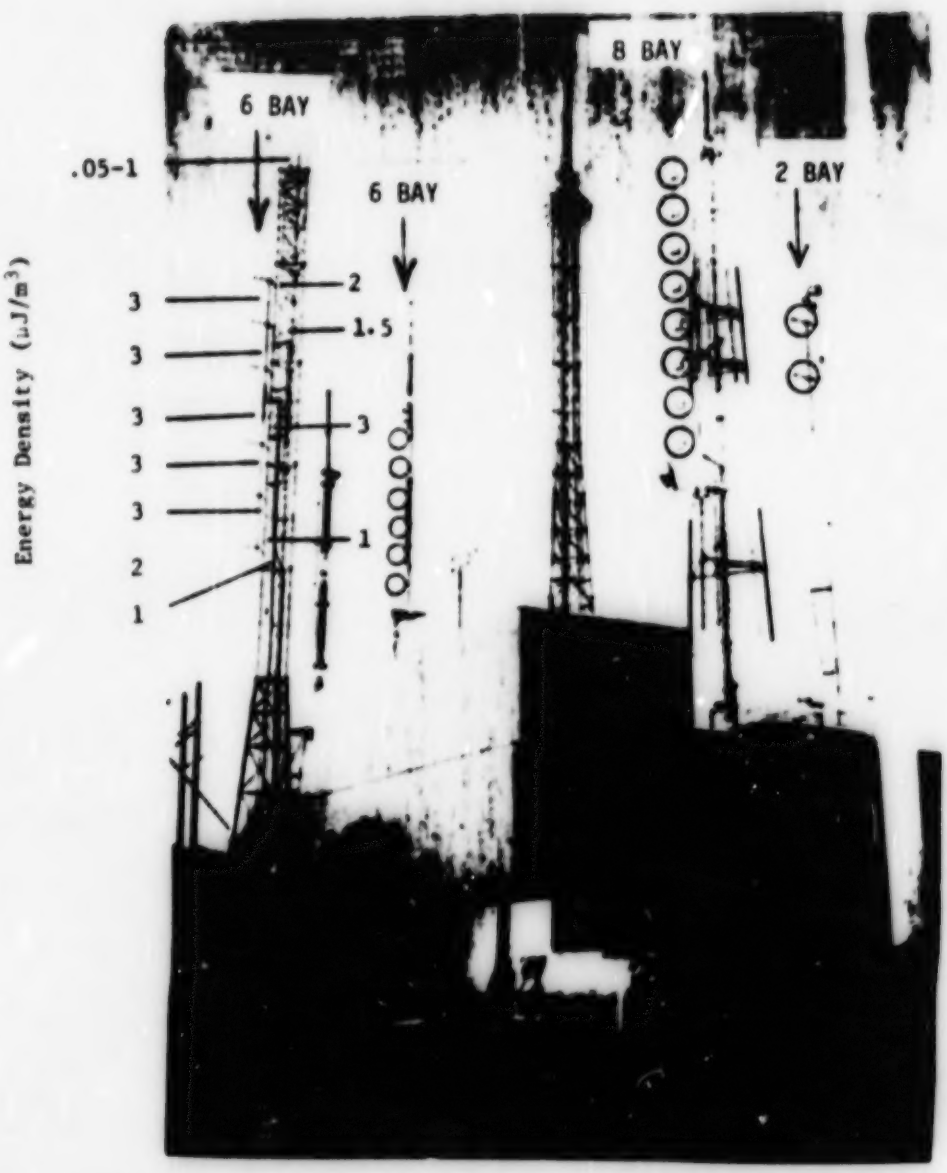

Figure 1. FM and TV Broadcast Towers on Mt. Wilson Showing Measured Values of Radiation Exposure (Energy Density in $\mu J/m^3$) on Tower at Left. Three Other FM Antennas Are Also Shown with the Number of Bays Shown for Each. Equivalent Far Field Power Density (mW/cm^2) Is Obtained By Multiplying Indicated Energy Density Values By 60.

measure of exposure only from the electric field and provide no insight to the magnetic field exposure. Since these measurements were taken in the near field, the data are presented in the measured units of $\mu J/m^3$ and V^2/m^2. Computed values of the far-field equivalent power density are also given in mW/cm^2. The EDM-3 has a usable frequency range from 3 to 3,000 MHz with a response within ±1 dB over the range of 10-1,000 MHz. It has a 50 dB dynamic range and is completely portable. A discussion of the development of the EDM-3 can be found in the literature [12].

A quantitative comparison of the measured field intensity by the EDM-3 and a spectrum analyzer with calibrated half wave dipoles was made in the far-field in the vicinity of the tower's base. In this case values obtained with the spectrum analyzer were within 0.8 dB of the values obtained with the NBS probe.

Measurements of the electric field energy density made with the NBS probe at various locations on the tower were called out to one of the survey team stationed at the tower base who recorded the data. The duration of the measurements, climb and descent, was about 20 minutes.

The approximate location of the measurement points are shown in Figure 1 together with the measured values of electric field energy density, U_E, in units of $\mu J/m^3$. The equivalent values of far-field power density, S, and the square of the electric field strength, E^2, as obtained from Equations (1) and (2) are given in Table 1. The highest value of energy density measured directly under the towers on the ground was 0.032 $\mu J/m^3$.

Table 1. Equivalent Energy Density, Power Density, and Electric Field Strength Measured on FM Tower

Energy Density ($\mu J/m^3$)	Far Field Power Density (mW/cm^2)	Electric Field Strength Squared $(V/m)^2$
.032	1.9	7,200
.05	3	11,300
1	60	678,000
1.5	90	339,000
2	120	452,000
3	180	678,000

These results, though not a detailed mapping of the tower radiation levels, do show that the intensities can be very high. In addition there are locations on the tower where the field intensity was well beyond the instrument's full scale reading of 3 $\mu J/m^3$ (equivalent to 180 mW/cm^2 in the far field) due to field intensification between two conducting structures. The values reported here are fields typically encountered when climbing the tower. Higher levels might be encountered depending on the maintenance task

to be performed. For example in many locations the hands are placed on ladder parts where exposures were in excess of the meter's capability.

Since this particular tower was in the immediate area of a number of other towers on Mt. Wilson, it is necessary to examine the possible contribution of nearby stations to the measured exposure values. The radio-frequency fields of other sources within approximately 500 feet of the FM station were calculated assuming that the contributing exposure was due to main beam radiation. This is a conservative approach in that it will overestimate any possible contribution. The total maximum exposure due to all sources other than the FM station in question was determined to be 27 mW/cm^2. In all probability the field would be substantially (at least a factor of 10) below this value since most of the tower is below the main beam of radiation of the other sources. Therefore, it seems reasonable to conclude that the fields measured on the tower are due principally to the antenna mounted on the tower.

DISCUSSION

From an examination of the data it is clear that exposure intensities on FM broadcast towers can exceed the OSHA recommended safety level of 10 mW/cm^2 by more than a factor of 10. The upper limit of exposure was not established since the radiation fields exceeded the range of the instrument. While these measurements were made on one of the more powerful FM stations in this country the results can probably be applied to all but the most minimally powered FM stations. This is because the localized field intensity near any given radiator (antenna bay) is dependent upon the fraction of the transmitter output power fed to it; this means that the local field near the elements of a single bay antenna may approximate the fields near a multiple bay antenna which is fed with significantly more power; i.e., input power per bay is more significant than total station ERP. Thus, a relatively low ERP station with few antenna bays may produce local fields near its antenna elements nearly as intense as a higher ERP station using more antenna bays. While these results apply strictly to FM broadcast stations, they raise very serious questions about the fields on television broadcast towers where the antenna input powers can be several orders of magnitude greater than that used in the FM broadcast service. The AM standard broadcast service operates at frequencies (0.54-1.6 MHz) below the 10 MHz lower frequency limit of the OSHA standard. However, there are very intense surface field gradients on AM towers [4] and fields on AM antenna towers may also be of concern. Additional studies are needed to determine if the exposure levels found on FM towers are also present on AM and TV broadcast towers.

Simple methods for controlling exposure of workers on broadcast towers are not immediately obvious. The OSHA standard permits higher exposures for periods less than 6 minutes; in these cases an exposure energy density value of 1 $mW\text{-}hr/cm^2$ shall not be exceeded. Thus, no upper limit is placed on short time exposure except that the higher level exposure may not occur more than once in each successive six minute period. Table 2 summarizes exposures and their associated durations permitted by the OSHA standard.

Table 2. Exposure Power Density and Duration Permitted by OSHA Standard for Whole or Partial Body Exposure

Exposure Power Density (mW/cm^2)	Exposure Duration (min. or sec.)
10	6 min. or longer
20	3 min.
30	2 min.
50	1.2 min.
100	36 sec.
150	24 sec.
200	18 sec.
300	12 sec.
500	7.2 sec.

As an example the OSHA standard would technically permit an individual to be exposed to 100 mW/cm^2 for a period of 36 seconds if there is a "cooling off" period of 5 minutes and 24 seconds following the 100 mW/cm^2 exposure before it was commenced again. These OSHA limitations apply to partial body as well as whole body exposure. The variability of the fields, the lack of instrumentation, and variable exposure durations of workers on broadcast towers would seem to suggest difficulty in compliance with this standard. Commonly mentioned durations for tower work reach several hours. Just the time it takes to safely climb up a modest height tower (200 feet) and climb down again implies relatively high exposures which will exceed minutes in duration.

The U.S. Army and Air Force have already recognized the need to limit the maximum possible exposure and have set an absolute upper limit of 100 mW/cm^2 regardless of how short the exposure time [13]. In actual practice, the Army uses an upper limit of 55 mW/cm^2 which corresponds, for the Army-Air Force standard, to a 2 minute exposure. Exposures of less than two minutes duration are deemed impractical to control. If a minimum exposure duration of 2 minutes is used with the OSHA standard, the maximum allowable exposure level is 30 mW/cm^2. In this context it is interesting to note that the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a maximum level of 25 mW/cm^2 for any exposure duration [14]. Since exposure times of less than 2 minutes are not simply controlled, it is felt that exposure to levels exceeding the equivalent of 25-30 mW/cm^2, or 94,000 to 113,000 V^2/m^2 would be difficult to control in terms of the OSHA standard and exposure to levels exceeding these values should not be permitted. Because of the relatively continuous nature of exposure on broadcast towers and the requirement for close attention to the work, this conclusion seems consistent with the philosophy expressed in the OSHA regulations. A further complicating factor is that portable, inexpensive instruments for measuring fields in this frequency range are not available. It does not seem practical to develop an instrument which would track the OSHA standard and indicate how long an individual might remain in one

location, tell him where to move to recover, and still be portable enough not to interfere with whatever task is being performed. Nor does it seem feasible to train personnel to make their own evaluation using presently available instrumentation. In our limited experience tower workers are not aware of the significance of thermalizing exposures and cumbersome safety considerations are apt to be discarded or ignored under the pressures of getting the job done. The most effective method of controlling excessive exposure would be to turn off or drastically limit the power fed to the antenna while the necessary work is done. This would probably require a rule making procedure by the FCC or promulgation of specific work procedures for broadcast towers by OSHA.

SUMMARY

High intensity radiofrequency fields on an FM broadcast tower have been found which require careful attention to prevent personnel exposures from exceeding OSHA regulations. These exposure levels are probably common to localized areas near antennas of all but the very lowest powered FM stations. The simplest method of control appears to be to turn off the transmitter while work which requires people to be on the tower is done. Alternative means to determine if compliance with safe practice is being met while working on energized towers will be cumbersome and probably impracticable. Television towers are also suspected of having very high levels near the antenna since they have significantly higher powers than FM broadcast stations. Standard broadcast AM towers may also be of concern because of high surface fields on the tower. Additional studies are needed to determine if the exposure levels on FM broadcast towers are also present on AM and TV broadcast towers.

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